SOUTHERN DUCTILE CASTING COMPANY,
BESSEMER FOUNDRY
2217 Carolina Avenue
Bessemer
Jefferson County
Alabama

HAER No. AL-125

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HISTORIC AMERICAN ENGINEERING RECORD

SOUTHERN DUCTILE CASTING COMPANY, BESSEMER FOUNDRY

HAER No. AL-125

Location: 2217 Carolina Avenue, Bessemer, Jefferson County, Alabama 35020. Birmingham Industrial District. UTM: 16-505940-3695860

Date of Construction: 1937

Present Owner: Citation Carolina Corporation

Present Use: Jobbing foundry manufacturing five grades of ductile iron for automotive parts, material handling parts, construction and industrial hardware, pumps and meters, tools and machinery, agricultural implements, oil field equipment, electrical pole hardware, and water and gas line fittings.

Significance: Southern Ductile grew from a very small, unautomated, traditional jobbing foundry into a highly mechanized and automated firm, generally uncharacteristic for the type of contact work it did. It was one of the first in the Birmingham District to implement ductile iron that, over the course of its first thirty years, virtually replaced malleable iron and severely limited foundry steel production. Further the company survived a pollution crisis that forced the closure of several similar firms, by adapting more expensive, but cleaner electric induction furnaces that ultimately proved to be not only a solution to their clean air concerns, but also an ideal medium to manufacture ductile iron.

The company that began as Jones Foundry in 1935 is marked by a tripartite history of two distinct and opposing periods separated by a transition period. From its simple beginnings through the 1990s, Jones Foundry was run by either founder Gibb Jones, his son Jack Jones, Jack's wife Betty Jones, or by businessman Morris Hackney.

During the first period, which lasted nineteen years (1935-1954), career jobbing foundryman Gibb Jones managed the company as a small family business and traditional jobbing foundry. Operating with a constant "hands-on" presence, he implemented very few automated procedures, cast large or limited run items, and maintained minimal record keeping. Through the second and transitional phase, from 1954 to 1969, Jack Jones, with a background in the early foundry and the military, operated the company with a similar hands-on, limited record keeping approach as his father, but introduced several labor-saving and production-increasing devices and incorporated a fairly new and revolutionary type of iron into production at the firm. In the third phase, beginning in 1975 and continuing through 1995, businessman and U.S. Naval Academy graduate Morris Hackney purchased the foundry and renamed it Southern Ductile Casting Company. Befitting its new name, Hackney ran the firm less as a family organization and more as a corporation, primarily concerned with profits and production levels. In stark contrast to Gibb Jones, he made dramatic managerial and operational changes during his first six years, completely altering the means to melt iron and make molds.

The company originated in the context of the Birmingham District of Alabama. All of the owners and presidents of Jones Foundry and Southern Ductile were born in Alabama's mineral region, probably to parents who moved there to partake in the rapidly developing industrial economy in the latter 19th and early 20th centuries. The region was sparsely populated through the 1860s, although iron and coal deposits had been known for several decades. Alabama's antebellum dependence on cotton completely overwhelmed the state's economy and little industrial development occurred until the Civil War created a Southern demand for iron.

Following the War and destruction of nearly all iron making and manufacturing facilities, a group of Montgomery, Alabama, businessmen with ties to developing railroads formed a company to purchase land at the pending junction of two railroads in the mineral region of North-Central Alabama. With the intention of selling lots and developing an "industrial city to take advantage of the immense natural resources in Jefferson County," the group founded Birmingham in 1871.[1] Large scale mineral exploitation began in Jefferson County soon thereafter, and the five surrounding iron and coal rich counties became known as the Birmingham District. Between 1880 and 1900 more new blast furnace companies opened in Birmingham than any other region in the United States except Pittsburgh, prompting Andrew Carnegie to declare the South, "Pennsylvania's most formidable industrial enemy."[2] By 1900, Birmingham had become Alabama's largest city, with a population of 38,000.[3] Within thirty years it expanded its boundaries and had grown to 259,000 persons. Jefferson County, with a 1930 population of 431,000, ranked as the largest county in the South behind Orleans Parish, Louisiana.[4]

Early hopes had centered on using Alabama's iron and coal to produce large volumes of high quality steel. Although the chemical and structural properties of the region's materials undermined these early hopes, the materials did combine to make ideal foundry iron, spurring a ten fold increase in pig iron production during the 1880s. The district quickly became the largest and least expensive foundry iron producing region in the country.[5] Enamored by its fast growth and success, Birmingham adopted the nickname "Magic City." Many foundries opened in the Birmingham District through the turn of the century, such that by 1914, Alabama ranked fifteenth in the number of foundries per

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[1]Robert S. Newbill, "A Study of the City of Birmingham's Corporate Boundaries from 1871 to the Present," unpublished report located in the Southern History Section of the Birmingham Public Library.

[2]For an analysis of the development of Birmingham's blast furnaces see Jack Roland Bergstresser, Sr, "Raw Material Constraints and Technological Options in the Mines and Furnaces of the Birmingham District, 1870-1930," (Ph.D. dissertation, draft copy, Auburn University, 1993) p. 1. For the reaction of Pennsylvania industrialists, see C. Vann Woodward, Origins of the New South, (Baton Rouge: Louisiana State University and the Littlefield Fund for Southern History of the University of Texas, 1951) p. 128.

[3]Marjorie Longenecker White, The Birmingham District: As Industrial History and Guide, (Birmingham: The Birmingham Historical Society, 1981) p. 68.

[4]"Mechanical Engineers Visit Birmingham-City of Destiny," Iron Age 127 (April 30, 1931): 1458.

[5]See Woodward, Origins of the New South, p. 127 and Bergstresser, "Raw Material Constraints and Technological Options in the Mines and Furnaces of the Birmingham District," p. 3.

state and by 1926 Birmingham ranked was twenty-ninth in the number of foundries per city.[6]

Although the mineral region centered on Birmingham, several other communities developed at nearby resource outcroppings. Bessemer, located ten miles southwest of Birmingham in Jefferson County, grew as a civic base from which to exploit iron and coal reserves in the southern portion of the county. Founded sixteen years after Birmingham, Bessemer developed in the shadow of its northern neighbor, never achieving a similar level of financial and industrial independence.

Amid Birmingham's boom period in the 1880s when, "most anything in the shape of space covered with dirt, brought almost its covering in greenbacks," Birmingham District industrialist Henry DeBardeleben "awakened to fact that...money was to be made in new town building as well as iron making."[7] DeBardeleben sought capital from South Carolina investors to construct a town centered around blast furnaces and central to the coal and iron ore mines being developed by the newly incorporated DeBardeleben Coal and Iron Company.[8] He selected a site "high and thoroughly well drained, so ample and eligible for construction and industrial purposes,...so central to supplies in iron production and various industries...it did not require too much thought of Mr. DeBardeleben and his associates to...launch a town...[that] would make a rival to Birmingham."[9] Creating a city whose industries would "bridge the gap between iron and steel," DeBardeleben named the town Bessemer, in honor of Sir. Henry Bessemer, the British engineer usually credited with inventing the converter method of steel making. On January 7, 1887, the Bessemer Land and Improvement Company held its first stockholder's meeting, capitalizing the firm at $2,500,000. It slated $2,000,000 to purchase property for the new town and $500,000 to lure new industry to Bessemer.[10]

The firm devised four methods to attract industry to Bessemer: it would provide either a cash or stock bonus, donate

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[6]See "Foundry Count," published in Foundry 44 (September, 1916): 376 and Foundry 66 (September, 1928): 744.

[7]Quoted from a "Special Illustrated Addition" on the history of Bessemer in the Bessemer Weekly, May 18, 1901 which provides a period description of the city and the history of the then twenty year old town.

[8]See "History of Bessemer," unpublished pamphlet produced by the Bessemer Hall of History, Bessemer, Alabama, 1987, for a short history of the city.

[9]Bessemer Weekly, May 18, 1901.

[10]"History of Bessemer," Bessemer Hall of History.

land, make cash loans, or some combination of the three based on the estimated value to the new city. This plan worked quite well initially. Within the first year, a group from West Virginia constructed a "new mill" with assistance from the land company and, on January 8, 1888, aid was approved for the Bessemer Fire Brick Company, Little Bell Furnace, and the Bessemer Steel and Iron Company.[11]

One of DeBardeleben's most successful projects, however, was the establishment of an iron pipe foundry within the city. In 1890, the land and improvement company gave 80 acres and $96,000 to a St. Louis iron firm to form the Harrison Pipe Works. The pipe company became part of the American Pipe and Foundry Company in 1898 before being taken over by the newly incorporated U.S. Pipe and Foundry Company in 1899.[12]

Through its early history, Bessemer thought of itself as an industrial rival to Birmingham. In addition to adopting a similar nickname, the "Marvel City" hoped to create a separate Bessemer County and build an independent 20 mile canal to the Warrior River.[13] Unsuccessful in its separatist efforts and frustrated by a poor self image, turn of the century editors claimed the city's iron industries were of the "cruder and grosser form..without manufactures of machinery, tools, boilers, hardware, ...implements, stoves...or of the hundred and one articles of utility and daily necessity.."[14] The city's only relief from the "unholy domination of Birmingham politicians" came in 1922 when Bessemer was provided with a division of Jefferson County government which included a court house to serve the western part of the county.[15] Following its early successes and later frustrations, Bessemer continued developing in the shadow of Birmingham to become, by 1920, the fourth largest city in Alabama.[16]

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[11]Ibid.

[12]See "History of Bessemer," Bessemer Hall of History for the origins of the company and White, p. 54, for a discussion of the later changes in ownership.

[13]Bessemer Weekly, May 18, 1901.

[14]Ibid.

[15]"History of Bessemer," Bessemer Hall of History.

[16]Barbara Connell Bailey, "Ten Years of Trying: A History of Bessemer, Alabama, 1929-1939," (M.S. Thesis, Samford University, Birmingham, Alabama, 1977) p. 18.

Jones Foundry, Part I: 1935-1950

In 1935, Gibb Jones and his sons Gibson and Jack opened Jones Foundry on a residential block in Bessemer. Jones Foundry began modestly, with only five employees casting simple gray iron jobbing orders in a former horse stable in Bessemer, Alabama.[17] From the company's inception, founder Gibb Jones and later his son Jack and daughter-in-law Betty maintained a civic-orientated family operation.

Gibb Jones, the original owner and namesake, was born just northeast of Birmingham in St. Clair County on January 11, 1896. After attending first through fourth grades in a one-room school house, his father sent him to a boarding school in Irondale (a Birmingham District community) where he continued through the sixth grade. Although his formal public education ended here, Jones continued studying through ICS correspondence courses and, by the age of 14, had begun a pattern-making apprenticeship at the Woodward Foundry Company near Bessemer. After four years with Woodward, Jones took a pattern-shop position at the Goselyn Birmingham Machine Foundry working for his older brother. Jones stayed at Goselyn for a decade, advancing to pattern-shop foreman and then foundry superintendent. In 1924, he moved to Bessemer and began working for the Bessemer Foundry and Machine Company as superintendent, where he continued until the Great Depression closed the firm in 1931. For the next four years, he worked at a small foundry on Eighth Avenue in Bessemer until he left that company to start Jones Foundry in 1935 with his sons Gibson and Jack.[18] Gibson, the elder son, was born in 1917. Following completion of high school in Montevallo, Alabama, south of Bessemer, he returned to open the foundry with his father in 1935. Jack, born in 1921, worked in the foundry as he completed high school.[19] Together, the three ran the foundry until the start of World War II.[20]

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[17] The Western Star, Thursday June 6, 1991 "Jones Foundry: the molding of a man's life;" and personnel communication with Betty Jones, June 20, 1995.

[18] "Jones Foundry: the Molding of a Man's Life," The Western Star, June 6, 1991.

[19] Personal Communication with Betty Jones, wife of Jack Jones, June 20, 1995.

[20] Personal Communication with Gibson Jones, son of Gibb Jones, July 10, 1995.

Early Jones Foundry Technology

During that early phase, the foundry operated a basic "floor work" model. Molders conditioned sand in "windrows" along the foundry floor. After hosing the rows with water and adding new sand, a large machine called a molders helper followed the rows, mixed the sand and redeposited it on the foundry floor, before molders rolled portable pneumatic squeeze molding machines over the rows. These machines used match plates patterns, with cope and drag patterns fixed to opposite sides of a single plate. Moldmaking began as a flask was hand-filled with conditioned sand over a bottom board on the molding machine. The double-sided pattern was placed on the sand-filled flask and a second flask was then placed over the pattern and hand-filled with sand. The fixed squeeze head of the machine was then swung over the top flask, and the pneumatic lift compressed the flasks, compacting the sand around the pattern. After the squeeze, the mold halves were separated, the match-plate removed, and cores inserted before the two halves were reassembled.

Cores were probably made at Jones Foundry by mixing sand and an organic binding agent, either oil or molasses. The conditioned sand was placed in half molds, packed, removed, and assembled before being baked in an oven to set the binding agent that fused sand crystals. Finished cores were placed in mold cavities, where molten iron would fill the void between the core and the mold wall.[21]

Jones Foundry melted iron in two relatively small cupolas. Pig iron or scrap material was charged into a refractory-lined metal stack, layered with coke and limestone. A blast of air was forced into the hearth of the cupola, infusing the melting area with fresh air and increasing the combustion temperature. As the coke burned, iron melted and picked up additional carbon. Dripping to the sand floor, it poured out of a tap into a bull ladle. Impurities in the iron mixed with the melting limestone, forming a lighter material, slag, which flowed out of a higher tap. As the iron, coke, and limestone reduced, additional raw materials were layered on top, maintaining a heat that could effectively last for several hours or days.

The cupola was the least expensive and most common method of melting iron in a foundry. Its primary advantages, outside of cost, were continuous pouring and adequate high temperature control for good iron fluidity.[22] Of 5100 foundries in the

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[21]Personal Communication with Manly Thomas, son-in-law of Gibb Jones, July 24, 1995.

[22]See Richard W. Heine and Philip C. Rosenthal, <u>Principals of Metal Casting</u>, (New York: McGraw-Hill Book Company, 1955) p. 456, for a discussion of cupola practice.

United States in 1960, nearly forty-five percent used cupolas.[23] Considering that in 1955 iron foundries accounted for forty-five percent of all foundries, (probably consistent with 1960), and that cupolas were not refined enough for steel and nonferrous melting, it becomes apparent that most iron foundries in the country used cupolas.[24]

During its first period, Jones Foundry exclusively cast gray iron. The least expensive and most basic foundry metal, gray iron, with a relatively high carbon content, is ideally suited for cupola melting. It produces a hard, somewhat brittle casting, ideal for situations were cost is a factor, tensile forces are minimal, or abrasion resistance is desired. Malleable, the other primary iron produced through the first half of the 20th century, produces strong yet soft metal good for situations with high tensile forces or potential vibrational failures. However, it requires a lower carbon content, more refined chemical composition, and post-casting heat treatment to produce the desired effects.[25]

As a jobbing foundry, Jones kept automation to a minimum. Without a mechanical system to move batch quantities of iron to floor areas, molders hand carried fifty to sixty pound iron-ladened crucibles from the cupola to the molds arranged in rows on the foundry floor.[26] When the iron solidified after pouring, workers hooked the castings with hand-held rods and, beating them with hammers, disengaged them from the sand. The sand was left in windrows, while the flasks and bottom boards were stacked and the castings taken to cleaning areas.[27]

This basic form of foundry work produced difficult working conditions. Hosea Hudson, who worked under similar circumstances at a Birmingham production foundry, stated that it was "a hot and muscle weary job," performed where "the whole interior of the place was hot as living hell."[28] Workers in Jones Foundry began taking salt tablets as early as February each year to replenish

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[23]"Foundries to Spend More for Plant and Equipment," Foundry 88 (May, 1960): 137.

[24]See "6208 Plants Casting Metals in the United States and Canada," Foundry 83 (August, 1955): 114, and Heine and Rosenthal, p. 455.

[25]Heine and Rosenthal, p. 518-567.

[26]Thomas, personal communication.

[27]Personal Communication with Willie Ward, molder at Jones Foundry from 1959-1995, June 28, 1995.

[28]Hosea Hudson Black Worker in the Deep South, (New York: International Publishing, 1972) pp. 22-23.

what was lost to sweat.[29] A United States Department of Labor official, addressing the American Foundryman's Association in the early 1920s, confirmed these conditions in general, stating the "causes of the reluctance of young men to engage in foundry work have been given as low wages, unsanitary conditions, laborious work, monotonous routine,...and lack of proper incentives."[30]

Amid the demanding work, Gibb Jones maintained a firm hold and community spirit at the foundry. Very early on, he included family members in the company with the intention of providing a livelihood for them. Two of his sons, a daughter-in-law, and a son-in-law served as president or manager of the foundry, while at least three other members served in various office positions.[31] Rapport with the community and workers also appeared to be good. According to daughter-in-law and former Jones Foundry president Betty Jones, Gibb hired members of the high school football team to work night shifts during the early summers at the foundry.[32] His son Gibson claimed that both African-American and White molders worked "side-by-side" and received the "same pay and same benefits." Jones even fed striking workers after the International Molders and Foundry Workers Union established a local at Jones Foundry in 1948 and encouraged a walk out.[33]

For its first six years the firm operated according to these simple tenants. However, when World War II began, each Jones left Alabama to serve in the war effort. Gibb Jones moved to Marrieta, Georgia, to work as a mechanic at an aircraft engine plant and leased the foundry to Frank Wacker, who filled small jobbing orders. Sons Gibson and Jack each joined the Army Air Corps, while a third son, Bobby, enlisted in the Navy.[34]

Following the war, Gibb and Gibson returned to Bessemer to reestablish Jones Foundry, which had just received a large contract from Rheem to manufacture water heaters. Traditional floor molding techniques, however, were insufficient to meet the demands of this contract, which may have been influenced by the growing demand for housing following the war. Consequently, the company installed what Gibson referred to as "mass production"

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[29]Betty Jones, personal communication.

[30]C.C. Schoen, "Training Men for Foundry Duties," Foundry (undated facsimile of post W.W.I article, probably vol. 46 (January, 1918): 39.)

[31]Betty Jones and Manly Thomas, personal communication.

[32]Betty Jones, personal communication.

[33]Gibson Jones, personal communication.

[34]Ibid.

systems to reduce some of the heavy labor involved in foundry work and increased output capability. The first was an overhead monorail that allowed a ladle, filled at the cupola, to be taken to floor pouring areas where workers received iron in their crucibles to fill the molds. The second system was a series of fixed pneumatic molding machines.[35] Operating similarly to the portable squeeze machines, these molding machines jolted the flask to settle sand prior to the squeeze. Completed molds were then carried to floor areas, where they were poured from the mobile ladle-filled crucibles. The shake out was still performed by hand-held hooks and hammers, but flasks and bottom boards were now returned to molding stations.[36] Although both systems eliminated some level of hand labor, they primarily increased production as the firm grew following the war.

Jones Foundry, Part II: 1950-1969

The second phase of Jones Foundry began a few years after World War II. During this transitional period two dramatic changes took place at the firm. The first involved the installation of production systems geared toward increasing output and reducing labor costs. The second, and probably the most significant change in the company's history, was the elimination of gray iron casting and the exclusive manufacture of ductile iron.

In 1949, Gibson left the family foundry to open Pressure Cast Products in Birmingham, and brother Jack returned to run the company with his father. By 1952, Jack Jones had begun the process of taking over the foundry from Gibb.[37]

In the early 1950s, Rheem canceled its contract for water heaters. Reducing the company's dependency on near-exclusive or large contracts, Jack Jones decided that, from then on, no single customer would make up more than twenty percent of the foundry's production.[38] To implement this new policy, the company had to win more contracts and increase production. Moreover, opposed to the large or limited-order jobs his father pursued, Jack sought customers with small items ordered in large quantities. This change would be considerably easier to automate as patterns from most customers would be designed to standard sizes. Thus, a few standard machines could be used to manufacture many different products. In response to its multiple new customers' high volume, standard-size orders, Jack eliminated floor pouring and

[35]Ibid.

[36]Willie Ward, personal communication.

[37]Gibson Jones, personal communication.

[38]Manly Thomas, personal communication.

shake out and installed new jolt-squeeze match plate molding machines, a series of pallet lines, and an automated shakeout and sand handling system.

Affectionately referred to as bump-squeeze, or bump-bump, the new match plate molding machines vibrated the drag flask to settle the sand (released from an overhead bin) over the pattern and, with the insertion of a bottom board, rolled it over. A molder then placed a cope flask over the match plate and released sand into it prior to the machine-actuated mold squeeze.[39] After adding cores and assembling the halves, the flasks were removed and used to prepare the next mold.

Once completed, the flaskless molds were placed on wheeled pallet cars that replaced floor molding. These vehicles sat on rails that ran from molding machines to new pouring areas. Workers pushed the cars to the pouring areas where pourers placed jackets and weights on the molds to hold them together during pouring, which was executed by a mobile ladle attached to an overhead rail system eliminating hand-held crucibles.[40]

After pouring, the molds cooled and pouring workers pushed them to the new shake out where a single pallet car sat secured to a pivoting section of rail. A shake out worker released the rail and pivoted the car, allowing the mold to slide off the pallet car onto a vibrating shake out conveyor. The worker then pivoted the rail section back beyond the feed rail to a secondary rail system below. The pallet car, when released, rolled onto the lower rails and slid back to the molding areas where a second pivoting rail section allowed molders to roll the car up and onto the molding rail.[41]

The vibrating shake out conveyor transported sand and castings to a separating screen. Castings were removed by hand and the sand fell through the screen onto belt conveyors that transported it to storage bins. Typical sand systems at the time automatically added water and probably fresh sand to the used sand coming from the shake out. As it was released from the bottom of the storage bin, a muller mixed the ingredients and sifted the conditioned sand out of a hole and onto a belt-conveyor system. These belts transported and lifted the sand above the molding machines where plows directed it into storage bins and molders released it into flasks.

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[39]The early processes were described by Frank Paige, quality control, union vice-president, and Southern Ductile employee from 1979, in a personal communication June 28, 1995, and Moses Taylor, Southern Ductile molder since 1967, personal communication June 28, 1995.

[40]Personal observation of a similar system installed at Southern Ductile's Centerville, Alabama, foundry, July, 1995.

[41]Ibid.

Combined, these systems dramatically increased production and reduced the level of labor involved. Although they offered a level of automation not existing previously in the foundry, the systems were still somewhat primitive and inexpensive compared to what was available. Production firms at the time used powered conveyors, powered cupola chargers, and automatic cleaning machines with conveyors linking all parts of the foundry. Jones was constrained by its need to remain flexible, the size and site of the company, and the level of capital it could expend. It automated to the extent necessary to increase production, but not so much so that excessive capital, financing, or foundry rebuilding was required.

The second major development during this period was the introduction of ductile iron. Exhibiting characteristics similar to malleable iron, ductile was a soft, strong metal, not as susceptible to tensile or vibrational failures as gray. Unlike malleable however, it could be produced very cheaply simply by adding magnesium to molten gray iron. Introduced commercially in 1948, new owner Jack Jones began experimenting with various ductile recipes soon thereafter.[42] By 1956, he had perfected a procedure that began with a slightly different grade of cupola-made gray iron. After tapping it into a bull ladle, a graphite "bell" made of magnesium-impregnated coke was plunged into the molten bath, causing a bright and violent reaction that produced the desired results. Jones Foundry, one of the first in the district to make ductile, paid royalties to patent holder International Nickel for several decades.[43]

Across the country, ductile iron proved so commercially successful that from 1966 to 1985 its production increased nearly four times, while production of malleable iron dropped two-thirds and foundry steel dropped one half for the same period.[44] (The history of ductile iron and its impacts are discussed in more detail in the Appendix A, starting on page 52.)

Between 1955 and 1965, the company also installed cope and drag machines to make molds too large for the match plate machines. These were also jolt-squeeze operated but instead of making both halves at the same time, one machine made a cope and the other a drag. These larger machines required two workers to handle each mold half and were located in the area of the foundry nearest the cupolas.

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[42]Betty Jones, personal communication.

[43]Manly Thomas, personal communication.

[44]Metal Casting Industry Census and Guide.

Jack Jones still ran the firm with a hands-on presence and workers felt management was accessible.[45] He still hired locally, much like his father but, unlike Gibb and many other jobbing firms, was more progressive and continually updated equipment as the foundry grew. In the early 1960s he installed the first fully automated molding machines at the firm. Manufactured by Beardsley and Piper, these machines did not require much human effort beyond inserting cores. Proving maintenance-hungry and difficult to upkeep, however, they were removed by 1967.[46] During the same period Jack began planning a new foundry, to be wholly modern, use more automated equipment and rectify the current foundry's "bad location." However, in the late 1960s, he grew ill and completely withdrew the plans.

In 1968, Jack Jones passed away, leaving the foundry in trust to his wife, Betty, and their children. For three years the trust, with Betty Jones as president, continued to operate the firm with assistance from Gibb Jones and his son-in-law Manly Thomas. By 1971, however, the trust, amid a poor financial outlook, decided it no longer wished to operate the company and the bank managing the trust foreclosed and took over.[47] For the next four years, the bank ran the foundry until former customer Morris Hackney purchased the company.

Jones Foundry, Part III: 1975-1995

A Birmingham native, Morris Hackney attended the U.S. Naval Academy and served a tour of duty from 1953 to 1958. Afterward, he returned to Alabama and worked with his father at the Hackney Corporation, a chain link manufacturer. From 1966 to 1975 he served as president and chief operating officer, building the business, according to a Foundry Management and Technology article, into the largest chain link manufacturer in the world.[48]

In 1973, his father sold the company to a Texas firm. Morris remained on as president, but was released a year later due to managerial conflicts. According to R. Lee Sullivan in a

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[45]Henry Archie, Southern Ductile molder from 1965, personal communication, June 28, 1995.

[46]Manly Thomas, personal communication.

[47]Compiled from Betty Jones, Gibson Jones, Manly Thomas personal communications and "Southern Ductile Casting Company-History," (Southern Ductile single-page history and company description, ca. 1988)

[48]Robert C. Rodgers. "Citation Carolina's Foundries Take off," Foundry Management and Technology (promotional copy, July, 1990.)

Forbes article, Hackney was forced either to "look for a job or buy a business."[49] In December 1974, he purchased Jones Foundry, which had supplied Hackney Corporation with ductile iron fence post caps for fifteen years.[50] Although Hackney admitted to knowing very little about the foundry business, his management experience with his father's firm guided the transformation of a traditional, labor-intensive jobbing firm to a very modern production jobbing company.

The first changes he implemented were in foundry management, beginning with the cost accounting system. "As with many poorly managed foundries, there were no record-keeping systems in place at Jones Foundry," wrote Robert C. Rodgers in his 1990 article for Foundry Management and Technology.[51] Morris Hackney referred to the system as so archaic that nobody knew why the foundry was losing money.[52] He recruited R. Conner Warren as vice-president for administration to assume the roles of controller, personnel manager, data processing manager, and purchasing manager. These positions all were held previously, in addition to foundry manager, by Gibb or Jack Jones during their terms as president. Warren spent his first several months organizing the manual record keeping for accounting, production control, and quotation costing and pricing. Once established, he introduced a minicomputer to process data faster and more accurately, stating that, for 1976, "it was rather revolutionary thinking for any foundry to have a computer."[53]

The second business change came in cost estimating. Traditionally, costs for a particular job were estimated by the casting's weight that, because of complexity, could often be as much as 10 percent underestimated. Hackney and Warren changed the system to a price based on difficulty and time required to complete.[54]

However, as the management transformation unfolded, the foundry faced an air pollution crisis. Birmingham had been especially hard hit by air pollution. During a particularly bad period in 1970, doctors warned respirator patients to stay inside and avoid contact with Birmingham air, or even to "leave the

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[49] R. Lee Sullivan. "Up & Comers-Citation: Morris Hackney Jumped into a Business he knew noting about," Forbes 155 (May 8, 1995): 56.

[50] Ibid.

[51] Rodgers, Foundry Management and Technology.

[52] Sullivan, Forbes.

[53] Rodgers, Foundry Management and Technology.

[54] Sullivan, Forbes.

city's befouled atmosphere."[55] In March 1970, the Department of Health Education and Welfare designated the Birmingham District a federal air pollution control region and as such was to be placed on a federal time-table to execute air pollution control programs and receive matching implementation funding.[56]

The pollution problem associated with foundries had been understood for several decades. In 1956, the American Foundryman's Society published the Foundry Air Pollution Control Manual, and the Engineering Manual for Control of In-Plant Environment in Foundries. The air pollution control manual stressed positive community relations and recognized the effects of air contaminants on vegetation and humans, citing the London Fog, that killed 6,000 people.[57] Because of the prohibitive costs of installing abatement equipment, especially when the majority of the firms in the industry were sparsely capitalized, little was done until the Clean Air Act and its associated regulations forced the industry to change in the early 1970s.

The federal government was hesitant to provide funding, however, because Alabama's law was seen as too lenient on certain polluters, allowing a seven year grace period before "grand-fathered" companies had to comply.[58] Because of the law, matching funds were not recommended, but the National Air Pollution Control Administration offered to help the state draft new legislation that would comply with the federal Clean Air Act.[59] By 1972, a new law had been drafted. Cited in an annual report of the President's Council on Environmental Quality as "an example of the mounting commitment of many state governments to preserve and enhance the environment," it was implemented on January 28, 1972.[60] The new law required polluters to have, or

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[55] William Sartor. "Air Standards too Strict, Executives tell Commission," Birmingham News, (October 3, 1970.)

[56] Anita Smith, "Air Pollution Area to be Designated," Birmingham News, (December 18, 1969) and William Sartor, "Air Pollution Cleanup awaits Federal Funding, Birmingham News, (March 9, 1970.)

[57] Foundry Air Pollution Manual, (Des Plains: American Foundryman's Society, 1956.

[58] Kate Harris, "Fingers Crossed, State asks for Air Pollution Funding," Birmingham News, February 7, 1970).

[59] Anita Smith, "HEW may Steel State's Smoke in Pollution Battle," Birmingham News, (April 3, 1970) and "Federal Air Standards in State Urged," Birmingham News, (April 4, 1970).

[60] "Pollution Laws Cited as Example," Birmingham Post-Herald, (August 8, 1972).

at least have applied for, a permit to operate. To qualify for a permit, a company had to establish a reasonable time-table for the installation of abatement equipment. Permitted companies generally had until 1975 to comply, and extensions were granted only in "extremely justifiable cases."[61]

Although the new regulations were heralded by many as a first step in eliminating pollution problems, they proved particularly difficult for small firms to meet, especially unautomated jobbing foundries. In 1972, several foundryman discussed the impact of new regulations on the industry, noting particularly the hardships expected for small firms. Speaking for the Alabama Foundries Association, Warren C. Jeffery pointed out that about one third of Alabama's 89 foundries employed less than twenty-five workers and only a few of those were large enough to absorb the cost of abatement equipment. Dan Saltsman Jr., vice president of U.S. Pipe and Foundry Co., stated that smaller foundries, in response to the regulations, would have "to invest more in capital and control equipment than is represented by the value of their entire foundry." Stanley Lawler, of Lawler Machine and Foundry Co., estimated that costs for his seventy-two person firm to comply with the regulations would more than double his entire capitalization.[62] In 1978, reflecting on the decade of pollution regulations and echoing concerns felt in Birmingham, Robert Wright, president of the Industrial Gas Cleaning Institute, Inc., claimed:

> One area of industry that has been hurt by air pollution control standards...is the foundry industry....About 30 per cent of small casting companies in the United States are no longer around because of clean air standards."[63]

In 1972, Jones Foundry, under bank management at the time, contracted with American Air Filter Company to install air scrubbers and dust collectors on its cupolas to meet Alabama's January 1, 1975, regulatory deadline. Design complications, however, delayed construction until May, 1976, but the foundry received continuation waivers and remained open.[64] Upon his

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[61]Kate Harris, "Polluters must have Permits," Birmingham News, (March 18, 1972).

[62]Stewart Lytle, "State Air Curbs see Small Foundries Death," Birmingham Post-Herald, (January 8, 1972).

[63]Charles Nix, "Middle Ground Sought on Control of Air Pollution," Birmingham News, (January 8, 1978).

[64]Letter from Jones Foundry to Jefferson County Board of Health, April 2, 1975 and Jefferson County Board of Health Resolution, May 21, 1975.

purchase of the firm in December 1974, new foundry owner Morris Hackney had to respond to the new regulations and complete the abatement project or face closure. The American Air Filter system he completed included sealed cupola caps and takeoff sections to capture emissions, gas burners to combust carbon monoxide and other carbon by-products, a spray cooling tower to lower gas temperatures and provide a dust drop out area for heavier particles, and a baghouse to filter exhaust gasses and collect finer particulate matter prior to atmospheric discharge.[65] The cost for the system was estimated at $365,000; over twenty-eight percent of the purchase price of the foundry.[66] To pay for the system, Hackney applied for two long-term bank loans, but was rejected like most small firms because of the size and capitalization of the firm. Turning to the Small Business Administration (SBA) for funds, Hackney cited the inability to continue operations without equipment under the Alabama Pollution Control Act of 1971. On January 5, 1976, the SBA approved the long-term loan and by the end of May, 1976, the new pollution system was installed.

The system appeared to work initially and the company continued to operate. Eighteen months later, however, Charles B. Robinson, Assistant Director, Bureau of Environmental Health, Jefferson County Department of Health sent the following to the SBA:

> The Jefferson County Health Department has recently pointed out to Jones Foundry Company that their present desulphurizing and nodularizing operation is in violation of present Air Pollution Control Rules and Regulations. The present amount of fugitive emissions caused by their desulphurizing process is above acceptable levels.[67]

The method Morris Hackney used to make ductile (nodular) iron was the same introduced by Jack Jones in the 1950s: magnesium-impregnated coke plunged into a ladle of cupola-melted gray iron. This method resulted not only in high levels of sulfur dioxide, carbon monoxide, solid waste, and dust from the cupolas, but also provided a magnesium oxide emission level of 13.5 tons per year, above minimum levels. Further complicating the problem, the baghouse system installed in 1975 was prone to

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[65]American Air Filter proposal for cupola emission control equipment made to Jones Foundry, March 27, 1974.

[66]Jones Foundry estimated cost summary for pollution equipment, November 1, 1975.

[67]Detailed in a letter from Charles Robinson, Jefferson County Board of Health, to James Barksdale, Small Business Administration, November 30, 1977.

leakage and was expected to worsen over time. In 1977, Hackney eliminated the cupolas entirely and installed electric furnaces.[68]

Electric furnaces substantially enhanced the company's ability to comply with increasingly more stringent environmental standards. Not only did they reduce carbon monoxides, smoke, and dust associated with cupola melting, but they also lowered magnesium oxide emissions seventy-five percent by placing purer magnesium directly into the ladle in exact proportions, thereby reducing the emissions related to excessive magnesium reactions with the iron and coke sulphur. Additionally, slag and other solid wastes, amounting to ten tons landfilled per day, could be eliminated.[69] (See Appendix B, page 64, for more complete discussion of induction furnaces.)

The furnaces also provided a higher degree of control over the melting process than coke-fired cupolas. The smaller furnaces could be poured in under twenty-four minutes from a cold start, required no fuel materials, could produce more accurately the chemical composition of the gray iron used in making ductile iron, and could use a wider variety of scrap because their inclusive crucibles did not require scrap sizes big enough to support coke, limestone, and more scrap layered above.

Instead of pig iron, coke, and limestone, the furnaces melted foundry scrap and a higher level of scrap steel. The materials passed through a preheater that raised their temperature with a less expensive fuel and removed any oils or moisture on the scrap that would react violently with molten iron. Following the preheater, a specially designed bottom-dropping charge bucket filled the furnace. Water-cooled, electrically-charged copper coils surrounding the furnace developed a magnetic field that reached into the furnace. This field then induced currents in the scrap metal loaded into the furnace. As the current passed through the material, discontinuities caused it to dissipate in the form of heat. As the electric charge continued, eddy currents circulated materials, increased the electrical activity in the crucible, and melted the charge faster.

The metal could be reduced in about twenty-four minutes. After it melted, the operator added several scoops of a slag coagulant to induce slag into larger quantities on the molten iron surface. He also added a fifty pound bag of graphite to increase the carbon content of the iron, which was generally low because of the high percentage of low-carbon steel in the batch. Upon completing the melt, workers placed approximately one quart

[68]Jones Foundry internal justification sheet, "Air Pollution Problems Benefited by a Switch from Cupola Melting to Electric Melting," 1977, and letter from Robinson to Barksdale.

[69]Ibid.

of magnesium chips into the bottom of a bull ladle. When the ladle was filled, the molten gray iron reacted with the magnesium, emitted a bright light and created ductile iron.[70]

While electric production of ductile iron worked quite well, it was an expensive system to implement. The price of removing the cupolas and installing two coreless induction furnaces and associated equipment came to $700,000. Instead of securing a direct loan from the SBA, Jones Foundry applied for specific pollution control financing, funded through civic bonds guaranteed by the SBA. This program, established in 1976, tended to ease the burden of small businesses where, according to Business Week, "environmental legislation hit the hardest." Only large business were able to take advantage of twenty to forty year low interest (5.5-7%) tax-exempt bonds for pollution projects, while small firms facing the same regulations could generally only get ten to twelve percent interest rates over very short terms.[71] The program guaranteed "payments under qualified contracts entered into by existing small business concerns which are, or are likely to be, at an operational or financing disadvantage with other businesses, for the purpose of acquiring pollution control facilities."[72]

Through the Industrial Development Board of the City of Bessemer, Hackney secured a bond issue for the necessary funds. The Board sold long-term bonds, purchased the furnaces and support equipment, including the overhead cranes, hoists, charge buckets, a scrap dryer, and related wiring and installation costs, and demolished the cupolas. As collateral, the company put up that portion of property that was being modified under the bond.[73]

Aside from the pollution advantages the furnaces provided, the combination of ductile iron and induction furnaces proved to be an ideal pairing for Southern Ductile. "Except for a few silicon control problems," explained P.S. Cowan of the Gray and

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[70]Process described in the "Permit Application for Manufacturing or Processing Operation," Jones Foundry submitted, probably to the city of Bessemer to operate its furnaces on November 22, 1977.

[71]"Now Small Business can pay its Pollution Tab," Business Week (November 21, 1977): 90.

[72]Described in "Application Guidelines and Procedures for Pollution Control Financing," U.S. Department of Commerce, Small Business Administration, July 15, 1977.

[73] Industrial Development Board of the City of Bessemer, "Inducement Agreement...with Jones Foundry," for the installation of coreless induction furnaces and associated equipment, January 3, 1978.

Ductile Iron Foundries Society, "ductile iron is easier to produce in electric furnaces than it is in cupolas."[74] Their primary advantages include the elimination of large amounts sulphur which, high in coke, readily combine with magnesium and reduce its nodular-graphite effects on the iron. Additionally, because it melts in a crucible-style hearth, a variety of scrap shapes could be used whereas a cupola required scrap that would structurally support and not slip down through the proportioned coke. Because of this, a greater control of the chemicals could be attained as well as less expensive materials.

Understanding the advantages of combining ductile iron production with induction furnaces, Swedish foundries implemented the combination as early as 1965. Primarily because of a lack of natural resources, induction furnaces were used to melt over one quarter of all Swedish cast iron, reducing the requirement for foreign pig iron and coke. As Sweden began large scale ductile iron production, foundrymen found the use of the in-place furnaces operationally ideal. Expressing these ideals, Bertil Hanas and S.E. Stenkvist wrote in the Journal of Metals in 1965:

> If electric furnaces, which usually require a higher capital investment, are considered, it is found that they produce a substantially better basic iron for ductile iron melting. Their advantages include the great flexibility in the size, analysis, and temperature of the melt, and the ability to adjust rapidly and simply...The risk of impurities from fuel no longer applies...and the capability of holding and storage of the molten iron [is another advantage].[75]

Even in areas of the world where pollution was not as highly regulated, induction furnaces clearly proved to be much more successful in producing high quality irons than had been expected. Although their initial costs were high, if forced to change, many firms found that the benefits many time equaled or even surpassed the costs. (See Appendices A and B for a detailed description of Ductile Iron and Induction Furnaces.)

Technology

Aside from implementing electric furnaces, Hackney undertook several other projects designed to increase production. Very soon after purchasing the firm, he installed a Hunter-10 Automated Match Plate molding machine, replacing one of the older

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[74]W.G. Patton, "Jobs Pile up for Ductile Iron," Iron Age 205 (May 21, 1970): 81.

[75]Bertil Hanas and S.E. Stenkvist, "Melting in Induction Furnaces for Ductile Iron in Sweden," Journal of Metals, 17 (March, 1965): 298.

pneumatic match plate molding machines. This new machine was almost completely automatic. Conditioned sand was delivered into an overhead storage bin, where it was infused with air to increase its compactibility. The drag half, fitted over one side of the match plate pattern, was filled first before being enclosed with a bottom board and rolled over. The drag, with the opposing match plate pattern side facing up, was directed under a cope flask that was also filled with conditioned sand. The whole unit was then squeezed much like before. When the mold was separated, the pattern was removed, cores were inserted, and the mold halves were reassembled before the whole mold was removed from its flasks and rolled onto the exit conveyor. Molders' only physical duties were to operate the machine controls, insert cores, and probably place the finished mold onto the pallet line.

Additional automated systems were delayed by the air pollution crisis that dominated the foundry for the next four years. In 1979, with their immediate pollution concerns behind them and electric furnaces melting iron, Hackney and Warren turned to expanding the firm. That year, they installed a second automated Hunter unit.[76] This one, however, was a Hunter-20, producing molds almost twice the size of the 10, and replacing another older match plate machine. The flasks, however, were too large to be moved by hand and a fork-truck was used to place the molds on the pallet lines for pouring; they were too heavy to push, and the company installed a cable system to pull the cars to the pouring area.[77]

Jones Foundry, under Morris Hackney's leadership, had already undergone drastic changes as the 1980s approached. In late 1980 or early 1981, Hackney changed the name from Jones Foundry to Southern Ductile Casting Company, seemingly in preparation for the elimination of the last vestiges of Jones-influenced operations and management systems.

In 1981, the company undertook the largest change in its history to date. Again utilizing a Bessemer Industrial Development (IDB) Board bond issue, the company borrowed $2,400,000 for capital improvements. Under similar terms, the IDB purchased the equipment and, with the improved space used as collateral, Southern Ductile made payments at a very low interest rate. The major projects undertaken with this issue included a new core room and pattern storage building, an office and associated equipment, a bathhouse, and telephone system. New equipment included cold box core blowers, high speed sand mixers,

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[76]Listed with the dates of installation on the "Fixed Asset Listing," of Southern Ductile, June 5, 1995.

[77]Moses Taylor, personal communication.

sand heaters, and a British Molding Machine (BMM) with its associated machinery.[78]

The BMM, reportedly one of only two similar automated cope and drag molding machines in the world, replaced the older, less automated cope and drag molding machines and practically eliminated all Jones-influenced mold making procedures. The single BMM made larger molds, separately squeezing cope and drag halves that were too big to be squeezed at the same time. Sand was automatically fed into an overhead hopper by belt conveyors, as patterns, situated on a cart, were aligned below. After the appropriate pattern was lifted into position under a flask, sand, aerated as it fell, was fed into it. Once filled, the squeeze head swung into place over the flask and a hydraulic cylinder forced the filled flask against the squeeze head and compacted the sand.

Each mold half left the BMM in its flask with its cavity facing down, as the other half was made. Associated machinery rotated the units almost immediately so that both cavities faced up to permit inspection and core placement. The next two units lowered flasks to the level of the pouring conveyor that serviced the older cope and drag machines, and assembled the two halves. Again, similar to the Hunters, the only human intervention in the process was to work the controls and place cores; all other manual functions had been automated.

A second system installed during this phase was a 35 ton holding furnace in front of the electric furnaces. The melting furnaces would be tapped directly into the holding furnace, from which the mobile ladles would be filled. The intention was to create as continuous molding as possible, eliminating the time pourers waited for a furnace to be ready to melt. A third system was a Shalco cold box core machine. This unit, as opposed to the ones described earlier, made cores from sand impregnated with a resin that set without heat. These units operated faster and more efficiently without heated core boxes. While they did not directly eliminate other core machines or workers, their high output was probably directly associated with the installation of the new molding machines.

The addition of new buildings and equipment dramatically changed the operation of the foundry. Over the next nine years, two more systems were installed to further automate the company, and additional furnaces and molding machines further increased output. The first of these new systems was an automated, oval mold-handling conveyor that replaced the pallet lines used with the Hunter match plate machines. This unit, built by Tru-Flo, maintained double width gondolas onto which two molds sat. After

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[78]Southern Ductile Casting Company described the projects they were going to execute in a paper entitled "Bessemer Industrial Development Board Bond Issue, Projects for 1981," June 28, 1981.

a flaskless mold was completed, it rolled into a pusher unit that placed it onto the gondola under a raised jacket with pouring weights. As the gondola moved, a bar that had been holding the pivot arm of the jacket down angled upwards, permitting the arm to raise and the jacket to lower over the mold. The mold traveled to the pouring area in the jacket, where iron pourers filled the molds from mobile ladles attached to overhead conveyors.

The iron cooled in the jacket until it approached the pushoff area where the restraining bar angled downward again, forcing down the jacket pivot arm, thus raising the jacket and weights. When the mold reached the pushoff area, a pneumatic arm pushed it into the mold with which it shared the gondola, forcing that mold onto the dump conveyor below. The pushed mold then traveled around the conveyor a second time on the back of the gondola, cooling, while another mold was placed on the front under the jacket and poured. When they reached the push off, the new mold was pushed into the first, forcing it onto a vibrating dump conveyor.

The new system dramatically increased output. Its double-width size increased the number of molds, reduced the floor space required for cooling, and eliminated shakeout and pallet car workers. Its speed, coordinated with the Hunters, regulated mold making and pouring, taking an element of passive resistance away from the workers. But it did create an excess sand problem as jacketless molds cooling on the inside gondola space had a tendency to loose their form and spill sand onto floor areas inside the conveyor. But with the reduction in the number of direct operating personal, many workers were available for service jobs such as reclaiming lost sand.

By 1987, Southern Ductile operated three Hunter molding machines, one 10 and two 20s, each with its own Tru-flo conveyor. All three Hunters and all three Tru-Flos operated the same, with the exception of flask size and direction of travel. Underneath all three, a single vibrating dump conveyor transported all sand and castings to the shake out. A similar vibrating conveyor took molds and castings from the BMM to its shake out. Vibrating conveyors offered two primary advantages. First its flat-"U" design provided fixed walls to keep sand and castings in. Second, it was made out of steel, which was not adversely affected by the high heat of the sand and castings. After the sand was separated from the castings, it traveled back to its respective sand storage bin either with the Hunters or the BMM, was reconditioned with water and fresh sand and, via belt conveyors, was delivered back the molding machines.

All castings produced at Southern Ductile then came together below the floor on a raising vibrating conveyor connected in series to a second, bench-level conveyor at the degating area, where workers broke off sprues and gates. On the first conveyor, they stood over the castings with sledge hammers and manually removed excess iron. For those castings that were too large or difficult, pneumatic wedge separators were used on the bench-level conveyor. Afterward, workers manually separated the castings into bins that were then transferred to the grinding area, where other workers cleaned casting surfaces in tumbling shot mills before grinding down gates and additional excess prior to shipping.[79]

The remaining equipment installed was either the same or very similar to what was already there. In 1988/1989, Southern Ductile added two high output cold-box core machines, without retiring the older heated plate machines. The first, a Laempe, automatically produced smaller cores on a thirty second cycle only requiring the operator to operate the controls and remove the core from the core box and package it. The second, a Beardsley and Piper Rotomold Cormatic, maintained three core boxes on a revolving turntable with three sand magazines on a similar turntable off-centered above. As the operator removed a core from one box, the most recently refilled sand magazine spun overhead and filled the corebox that was emptied just before. The sand cured during the third stage and cores were removed every thirty-eight seconds. Following the increase in coremaking, the company installed two more induction furnaces in 1989, doubling its output, and removed its 35 ton holding tank. In 1990, it replaced its original 1975 Hunter 10 with a 1970 model that operated more efficiently.

The effect of the systems installed by Morris Hackney were dramatic. In 1967, at the height of Jack Jones' tenure as president, the company had a one-year production rate of 3,620 tons of castings.[80] By 1983, following the installation of the first two Hunters and the BMM, production increased to 4,852 tons per year. Following the installation of the Tru-Flo conveyors in 1988 and the additional furnaces and higher output core machines in 1989, production reached 9,143 tons per year. After a slight down turn in the early 1990s, production reached 10,090 tons in 1992 and 12,811 in 1994, with projected output of 14,105 for 1995. Including the reduced output of 1990 and 1991, production increased an average of ten percent each year from 1984 to 1994.[81]

Conversely, the size of the work force did not change noticeably with automation. The period from 1967 to 1989 had a peak labor level of 227 in 1980, (just prior to the installation

[79]Personal inspection, July, 1995.

[80]Described by the company in the "Foundry Products Industry Response Sheet," for the Census of Manufactures, Bureau of the Census, U.S. Department of Commerce.

[81]Production records are maintained by Southern Ductile Casting Company in the file "Average Net Shippable Castings Manufactured per Week, Bessemer Plant," printed July 3, 1995.

of the BMM) and a low-level of 116 in 1975 (Hackney's first year with firm), averaging 164 workers per year. However, the composition of the force did change dramatically. The number of skilled workers dropped from an average of sixty eight in the mid 1970s (1973-1977) to just fifteen during the late 1980s (1985-1990). Similarly, the level of unskilled workers increased from an average of thirty-three in the mid 1970s to ninety-one in the late 1980s.[82]

The racial makeup of the company also changed during this period. From 1967 to 1980, the number of African-American skilled workers was as high as sixty-two percent; from 1981 to 1991, the number was as low as twenty-nine percent. Throughout the company's entire history, African-Americans filled the majority of semi-skilled and unskilled positions. Although racial distribution of the work force fluctuated, shifts can be attributed primarily to general Southern mannerism and Birmingham demographics.[83]

Worker reaction to new technologies was mixed. While eliminating many labor intensive operations eased working conditions, labor levels generally did not drop: skilled workers often were reassigned to lower-skilled jobs with less pay.[84] Further, the level of control workers had over the process declined significantly as machines actuated most production operations and ran at their own speed. Although labor relations remained fairly good through this era, workers resorted to passive resistance, such as absenteeism or slow work, to display their displeasure at job reassignments and loss of control over their jobs.[85]

Throughout this period, high levels of automation contrasted with labor intensive operations and unsophisticated system modifications. Workers wielded sledge hammers to break off excess cast metal and remove sand adhering to the inside of storage bins. All castings were worker-handled at least twice: once as they were separated at the degating area and again when they were ground to remove gates and packaged. Although the casting areas became highly efficient, the foundry operated somewhat awkwardly as fork trucks transported cores and hand-filled bins to molding areas and castings to surface cleaning, grinding, and shipping areas. Although the firm was limited by its site and level of capitalization, it operated harmoniously

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[82] Detailed in "Employee Information Reports" submitted annually by Jones Foundry and Southern Ductile to the Equal Opportunity Commission, U.S. Department of Commerce, 1966-1991.

[83] Ibid.

[84] Henry Archie, personal communication.

[85] Frank Paige, personal communication.

with the addition of relatively high numbers of fork truck drivers and probably had reached a maximum level of automation, as additional conveyor equipment would have required dramatically expanding and rearranging the plant.

The three periods of Jones Foundry's development accurately represent the personalities and experiences of the three different owners. Gibb Jones, who completed his education through correspondence school, specialized in foundry operations and made foundries his career from a very early age. From eighteen through the start of Jones Foundry, he had worked in jobbing and often small foundries. He carried these experiences with him, and ran his business similarly, with traditional labor intensive procedures maintaining all necessary records in his head. He created a successful firm and maintained it without alterations during his ownership. However, he was also a dedicated family man and had intended on passing the company down to one of his children. Thus, as soon as the firm was successfully established, he sold it to his son Jack and started another business.

With a lesser foundry background than his father and almost a ten year military career, Jack Jones ran the company with a greater impetus for change. While his father's management style influenced his record keeping and singly-operated management, he made several important changes at the firm. Influenced less by a lifetime in the foundry business and possibly more by the experience of the military, he did not limit the firm to old-style procedures and altered materials and products that lent themselves to business expansion and automation. With the transition to ductile iron and newer attitudes toward contracting and automating, Jack Jones significantly enhanced the company's ability to grow. Although he could not eliminate his father's influence completely, he did manage to bridge the gap and prepare the firm for its third phase.

The third owner, Morris Hackney, came from a business background and brought lessons learned from creating a leading manufacturing company. Making rapid changes to increase production and reduce labor costs, the firm grew quickly through his tenure. The 1970s proved to be a turning point for not only the company, but also the industry, and Morris Hackney made substantial operational changes to stay in business. The purchase price of the firm, added to the cost of implementing pollution control systems and the cost of the 1981 expansion meant that production had to be increased in order to generate the capital necessary to make payments. Further in the face of a slacking foundry industry facing pollution concerns, modernization was almost a necessity to reduce costs and remain competitive.

The jobbing foundry industry was particularly hard hit in the 1970s and early 1980s, as pollution regulations, recessions, and foreign competition reduced the number of small, low-capitalized firms. From 1963 to 1973, the number of jobbing firms dropped only two percent compared to an eight percent drop for the industry as a whole. From 1973 to 1983, however, jobbing firms experienced a twenty percent drop compared to a fifteen percent drop for all foundries.[86] Dramatic changes had to take place at Jones or else the company would sink with similar firms. Although articles on jobbing firms are usually scarce, many other firms were probably forced to make changes similar to Jones', if their production allowed it, to remain open. Measures to increase productivity had to be implemented. Ultimately, Jones Foundry's new systems, while more expensive to purchase and operate, not only permitted the firm to meet regulations, but also led to a higher quality product.

Jones Foundry, considered mismanaged at the time, appeared to be a sound investment in the early 1970s, even though it was losing money and faced a pollution problem. The dramatic changes that took place after Morris Hackney's purchase were driven by the solution to the air crisis. By installing induction furnaces to eliminate toxic cupola emissions, Hackney succeeded in merging two systems ideally suited for each other. While ductile iron was cheaper in the cupola, its manufacture in an induction furnace enhanced its quality and consistency, ultimately resulting in more business, especially as demand for it grew.

Ultimately, the systems installed by Hackney dramatically changed the foundry as it expanded production to meet growing demand. Not only did he eliminate the older, traditional means of running and operating a jobbing foundry, he successfully automated and increased business in a dramatic contrast to the labor-intensive, cupola-poured, gray iron jobbing foundry established in the horse barn in 1935.

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[86] Metal Casting Industry Census and Guide.

APPENDIX A
Ductile Iron

On May 7, 1948, at the gray iron session of the American Foundryman's Society Casting Congress in Philadelphia, members of the International Nickel Company introduced ductile iron to the public. Called "one of the most significant foundry advances of the modern times," it grew in production to become the second leading foundry metal produced by 1971, outpacing malleable iron, steel, copper alloys, aluminum, and all other foundry metals except gray iron.[87]

Iron is generally not pure Fe and carbon, but a combination of elements, including carbon, silicon, manganese, phosphorus, and sulphur arranged in specific compounds throughout the metal. Although each additional element ranges only from .05 percent to 4 percent of the total by weight, each exerts certain effects on the iron.

The most influential element, however, is carbon, and irons are broadly characterized by the level and shape of the carbon they contain. In molten iron, carbon exists completely dissolved in solution. As the metal cools, percentages of it disengage at the molecular level while the rest combines with Fe to form specific compositions such as hard and brittle cementite (Fe_3C), or a layered combination of cementite and softer, purer ferrite called pearlite. The carbon that precipitates out of solution forms graphite, or free carbon, gathered in either flake or sphere-like shapes within the matrix.

The portion of carbon that forms cementite can combine with iron up to fifteen times its own weight, rendering a four percent carbon iron, sixty percent cementite. The resultant mix is dominated by cementite characteristics and is a very brittle and hard material. Thus the need to encourage high graphite formation becomes critical to producing a usable iron. The remaining Fe that has not formed cementite generally forms ferrite or layered pearlite.

The primary irons used in foundry practice contain varying percentages and shapes of free and combined carbon and levels of cementite that broadly determine their properties. (See Table 1.)

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[87]"Ductile Iron Pioneer," <u>Foundry</u> 102 (October, 1974): 117 and <u>Metal Casting Industry Census and Guide</u>.

Table 1.[88]
Typical Iron Properties

Iron	% C	Compression Strength, 1000 psi	Tensile Strength, 1000 psi	% Elongation
Gray Iron	2.5-4.0	105-175	25-60	<1
Malleable Iron	1.5-2.3	90+	50-60	10-25
Ductile Iron	3.2-3.8	120-200	55-120	18
Carbon Steel	0.1-1.4	65-130	64-130	20-35

Gray iron has been the most widely manufactured foundry iron in the Unites States. It has a relatively high level of carbon, 2.5 to 4 percent, compared to other irons. As it cools in the mold, portions of free carbon precipitate out of solution in the form of flakes. The slower the cooling and the higher the silicon content, both of which encourage carbon precipitation, the higher the percentage of graphite, resulting in lesser amounts of cementite and generally a less brittle iron. Because of the level of visible graphitization, a broken piece of gray iron exhibits a gray, sooty surface.

The graphitic flakes, because of their length and alignment, tend to generate stress concentrations and propagate fractures that occur on the iron's surface.[89] Flakes, combined with higher levels of cementite (than other irons) result in a relatively hard and brittle iron with elongation of less than one percent. Despite its characteristics, gray iron has, however, still been the most widely used foundry iron. Its chemical composition permits it to be cupola melted in the presence of large amounts of burning carbon in the form of coke, the least expensive means of melting. Further, its in-mold cooling often effects a highly usable casting without the need for further treatment.

Gray iron castings, however, still need to cool slow enough to permit enough graphitization to occur. With smaller castings, which tend to cool too quickly, a higher silicon iron may be used

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[88]Adapted from Sylvia, pp. 234-235.

[89]P.J. Mafikiri, "The Design of a Complete System to Characterize the Melt Quality and Dimensional Accuracy of casting in a Ductile Iron Foundry," (M.S. Thesis, University of Alabama, 1991.)

to encourage free carbon formation. Larger castings generally cool slow enough and are made with irons of lower silicon levels. Most gray foundry irons are sold in grades based on the level of silicon they contain.

Besides low cost, several other factors added to gray iron's wide use. Its hard nature resulted in high compressive and torsional strength, and high wear and corrosion resistance. Its low elasticity tended to damp vibrations and, as an advantage over steel, its high fluidity permits more intricately designed castings obtained easier and cheaper.[90]

The second most commonly produced foundry iron, exclusive of steel, through the first half of the century was softer and stronger malleable or black iron. Considered by Richard Heine and Philip Rosenthal as occupying the "unusual position of being truly a product born of the American foundryman's inventiveness," it had a lower carbon level than gray iron, generally 1.8 to 3.6 percent, but required several more steps to create.[91] (See Table 1.) It began as cast white iron produced by rapidly cooling finished castings, often with water. Slow cooling prevented graphitization, leaving all carbon combined in cementite. When broken, the lack of free carbon resulted in a clean, almost white metallic surface.[92]

The high cementite of white iron resulted in very hard and brittle castings with very little strength to maintain tensile or compressive loads. Castings, however, did not remain in this state and the next production step significantly altered these properties to attain the desired malleability. Annealing, or slowly heating and cooling the finished white iron castings in large ovens, often for several days, broke down the molecular structure of the iron and the majority of carbon atoms disengaged from the cementite and precipitated out of solution in the form of graphite spheres. The remaining structure, with very little combined carbon, was mostly ferrite.[93]

This new arrangement produced two effects. First, when broken, the level of visible graphite presented a black and very sooty surface. Second, the more continuous and homogenous ferritic matrix and graphite nodules permitted the metal higher ductility than gray iron which, with higher levels of cementite and direct avenues for fractures to propagate, failed under certain loads requiring flexibility.

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[90] See Heine and Rosenthal, pp. 445-446 and Charles F. Walton, editor, Gray Iron Casting Handbook, (Cleveland: Gray Iron Founders Society, 1957.), p. 41.

[91] Heine and Rosenthal, p. 547.

[92] Ibid, p. 430.

[93] Ibid, p. 547.

Because of its properties, malleable iron proved ideal for situations where a material was required to absorb forces without failure and yet still provide high strength, ease of machinability, toughness, and corrosion resistance in certain applications. In 1956, forty-five percent of all malleable iron castings went into automobile parts and seventeen percent into pipe fittings.[94]

Because of the need to maintain more specific chemical compositions to create lower-carbon white iron, many malleable foundries melted iron initially in an open hearth furnace, which did not utilize direct contact with carbon-fuel sources. Although purer, the system was more complex and expensive than a cupola. Those firms that did use a cupola, however, generally had to add a duplexing or other type of holding furnace that, through its maintenance of a constant temperature for an extended period, reduced the excess carbon picked up during cupola melting. Additionally, after castings had been formed, they required rapid cooling to produce white iron and annealing to produce black; both of which required additional equipment and raw materials.

Overall, this iron was more expensive to produce than gray iron yet cheaper than steel, which required further processing and additional equipment. But, because of its applicability, malleable was the second most commonly produced foundry iron behind gray and the third most cast ferrous metal, behind gray iron and steel, through the late 1960s.[95]

Steel, the second most cast ferrous metal, has very little carbon, all of which is combined in cementite and appears with ferrite in a pearlite microstructure. (See Table 1.) Because of its tight chemical composition and the need to maintain lower carbon levels, most steel had to undergo an exhaustion process to reduce carbon and other undesirable elements before it could be cooled and used in a foundry. Similar to malleable iron, steel was mostly produced in open hearth or crucible furnaces that did not permit direct contact between carbon and the metal. Each primary process required extensive and costly equipment, but resulted in a much stronger and more ductile material.[96]

The tripartite domination of gray iron, malleable iron, and steel, however, changed dramatically in the second half of the twentieth century at the hands of another product born of American, albeit concurrent with British and German, inventiveness. In the spring of 1948 two groups announced the development of a formula for producing an iron with

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[94]Ibid.

[95]Metal Casting Industry Census and Guide

[96]W.L. Nelson, "Progress in Metals," The Oil and Gas Journal 40 (May 11, 1950): 102.

characteristics similar to malleable and steel, but made from the simple inoculation of less expensive gray iron with small amounts magnesium or cerium.

This new iron, called ductile or nodular, required a grade of gray iron, to which cerium or magnesium was added in the molten stage to promote nodular graphite precipitation. Possibly because of changes in surface tension during cooling, the free carbon took the form of nodules, similar to that in malleable iron, as opposed to typical gray iron flakes.[97] The resultant graphite spheres were surrounded by a level of purer ferrite in a larger matrix of pearlite. It was not the graphite spheres, however, but the matrix that had the greatest effect on the new iron's properties.[98] The resultant matrix, more homogenous than gray iron, was much more able to absorb shocks without failing. Further, the lack of elongated carbon deposits did not propagate cracks that would led to brittle gray iron failures.[99]

The most commercially effective benefit, however, was the fact that malleability could be achieved without, "the lengthy annealing of white cast iron." [100] Further, because of its relatively high carbon content, it could be melted as cheaply as gray iron in cupolas or, for tighter chemical control, electric or practically any other type of furnace.[101]

Before and during World War II, foundrymen in the United States, Britain, and Germany had experimented with the formation of nodular graphic precipitate in gray iron.[102] Although debate clouded the initial inventors, papers presented at the American Foundryman's conference in May, 1948, and the Institute of British Foundrymen in June, 1948, formally announced the discovery to the public. The American version, patented by International Nickel, used magnesium and the British version, patented by the British Cast Iron Research Association, used

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[97]Richard A. Flinn, Fundamentals of Metal Casting, (Reading, MA: Addison Wesley Publishing Company, 1963) p. 237.

[98]Sylvia, p. 238.

[99]See Sylvia, p. 239, Mafikiri, chapter 1, and "Ductile Cast Iron," The Engineer 199 (December 30, 1949).

[100]H. Morrogh and W.J. Williams, "The Production of Nodular Graphite Structure in Cast Iron," The Engineer 185 (May 12, 1948): 494 and "Some Notes on the History of Nodular Iron," Iron Age 163 (May 19, 1949): 100.

[101]"Ductile Cast Iron," The Engineer 188 (December 30, 1949): 766.

[102]"Some Notes on the History of Nodular Irons," Iron Age 163 (May 19, 1949): 100.

cerium.[103] Both formulas required the additional metals to be added just prior to casting to prevent them from burning off or combining with other elements in the iron which would form typical gray iron graphite flakes.[104]

Because its properties approached steel and retained the fluidity of iron, ductile iron proved ideal for "applications requiring mechanical properties better than those of gray iron and yet too intricate in shape to be cast in steel."[105] In 1950, Ford began experiments with ductile iron and found it a useful replacement for certain steel and gray iron castings, but did not see it as an immediate replacement for malleable iron.[106] Several other organizations also experimented with ductile iron in 1950. Their products included forging hammers, gas compressors, pistons, crankshafts, and kettles. This great early success precipitated a Steel author to describe the pace of experimentation as feverish, and actual service as beyond the point of mere speculation.[107]

By 1955, the role of ductile iron had become firmly entrenched, replacing many steel castings because of its lower cost, ease of casting, and better machinability. That same year, the American Standards for Testing and Materials, the AMS, the Navy, the Army Ordinance division, and the Society for Automotive Engineers all began the process of establishing specific standards for ductile iron.[108] By 1960, the actual automotive applications for ductile iron numbered twenty-three, with an additional thirteen expected.[109]

The decade of the 1960s demonstrated the widespread application of ductile iron, witnessing a ten fold increase in production by 1970. Although the methods of manufacturing changed little, experiments as a steel replacement and other applications continued. The Bay City Foundry Company of Bay City

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[103]Ibid.

[104]H. Morrogh and W.J. Williams, and F.R. Morral, "Nodular Irons," Foundry 78 (March, 1950): 135.

[105]Nelson.

[106]Gosta Vennerholm, H.N. Bogart, and R.B. Melmoth, "Nodular Iron finds favor with Ford." SAE Journal 58 (May, 1950): 31.

[107]"Nodular Iron's Record-Two Years Later," Steel 127 (July 17, 1950): 85.

[108]Thomas E. Eagan, "Field for Nodular Iron Continues to Grow," Foundry 83 (May, 1955): 119.

[109]W.H. Dawson, "Ductile Iron..Today and Tomorrow," Automotive Industries 122 (January 1, 1960): 50.

Michigan produced all of its formerly steel stamping dies of ductile iron, the American Cast Iron Pipe Company of Birmingham, Alabama manufactured ninety percent of its large pipe of ductile iron, and nearly all European pipe was made of ductile iron.[110]

More dramatically, however, was ductile's rise to foundry domination, replacing many malleable iron and steel applications from 1966 to 1985. In 1966, ductile iron was the fourth (of four) most commonly produced ferrous foundry metal behind, in order, gray iron, steel, and malleable. By 1968 it had surpassed malleable in production, and, by 1971, it had surpassed steel, becoming the second most produced foundry iron.[111] For the twenty year period from 1966-1985, it grew in production nearly four times and was the only foundry iron that experienced an overall increase in production. The summed amount of ductile, malleable, and steel castings made annually changed little during that period, remaining nearly four million tons per year. In 1966, ductile iron accounted for less than twenty percent of that total, while malleable garnered nearly thirty, and the remaining fifty percent belonged to steel. By 1985, however, ductile accounted for sixty-six percent, malleable only ten, and steel just twenty-four.[112] Ductile had nearly eliminated much malleable production and severely limited steel castings.

Although ductile iron replaced many ferrous applications, the industry as a whole faced a general decline over the same two decade period. In 1985, the foundry industry produced only fifty-six percent of what it had in 1966; gray iron production had dropped nearly sixty percent and copper-based alloys fifty-five percent. Although general industry conditions accounted for some of the decline of steel and malleable iron, ductile's rise suggests it not only replaced certain other irons and steel, but that new applications for ductile were being developed as well.

Jones Foundry adopted ductile iron relatively early following its introduction. By 1956, the iron had proven itself commercially viable, as many manufacturers and users of cast products began specifying it in their orders. The shift, still one of the earliest in the Birmingham District, proved successful as the company expanded through the next twenty years. For the firm, the next big change came in the late 1970s, as it installed coreless induction furnaces to replace its crude, pollution-intensive cupolas. Following that move the firm entered its third phase, highlighted by dramatically increased production.

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[110]Patton.

[111]<u>Metal Casting Industry Census and Guide.</u>

[112]Ibid.

APPENDIX B
Induction Furnaces

Electric furnaces played a major role in the foundry industry. Developed in the late 1870s, they permitted a dramatic increase in nonferrous founding and a wider use of foundry steel. More significantly, they yielded greater pollution control a century after they were invented and also proved to be a useful tool in the manufacturer of ductile iron.

The first interest in electric melting dates to 1800, when Sir Humphrey Davy built the first recorded electric furnace. Using a small arc created as an electric current between two electrodes, it produced sufficient quantities of potential melt metal. In 1849, Desparatz created the first resistance furnace that passed a current through an electrically resistant material which, becoming incandescent, gave off heat.[113] The primary drawback to large scale electric furnace development, however, was the lack of a consistent power source. Without consistent level of electricity, furnaces developed in areas with adequate power would not necessarily be commercially feasible in others. In 1881, the development and implementation of the dynamo made electric power available for wider applications.

Predating the dynamo by just three years, Sir William Siemens, credited with developing the first furnace with wide commercial applications, exhibited two arc furnaces; one with vertical and another with horizontal electrode arrangements. At his exhibition in 1878, he melted several pounds of steel and copper, demonstrating the furnaces' commercial capabilities; with the advent uniform power sources, they became relatively widely adapted.[114]

Over the next twenty years, several varieties of resistance and arc furnaces were developed as electrical services and electrode quality continued to improve. The primary improvements came as higher powered furnaces generated higher temperatures, melting metals more quickly and to finer degrees.[115]

Electric furnace designs in the 19th century, however, were primarily limited to arc and resistance types. In 1900 Kjellin developed the first low-frequency induction furnace that generated electric currents in the charge without direct electrode contact. Coils wrapped around a crucible generated currents that traveled through a liquid metal bath at furnace

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[113] Woolsey Johnson McA. and George N. Sieger, "History of Electric Furnaces," Metallurgical and Chemical Engineering 12 (January, 1914): 41, and Lawrence A. Hartley, Elementary Foundry Technology (Cleveland: Penton Publishing, 1937) p. 256.

[114] Johnson and Sieger, Metallurgical and Chemical Engineering

[115] Ibid.

bottom to a narrow refractory channel in a metallic core, creating in effect a closed circuit. Currents flowed through cold metal placed in the furnace, enlarging the circuit and generating enough heat to effect the melt.[116]

Applications of this furnace type, however, were limited. It could neither remove many impurities nor handle slag as easily as newer arc types or crucible furnaces could. Further, the melting space had to be as small as possible to attain the speed required to make the furnaces cost effective, resulting in small and, with the inplace core, relatively inaccessible hearths.[117] Because of these limitations, early induction furnaces did not receive much attention in the United States.[118] Described in an article published by Metallurgical and Chemical Engineering in 1914, the electric furnace had "reached the end of [its] first 'commercial' stage" in 1905, as developments in furnace design and consistent electricity continued to improve.[119]

The primary users of electric furnaces became steel and nonferrous foundries, which could not effectively melt these metals in direct contact with coke in the cupola. Because of steel's low carbon content and the possibility of contamination in nonferrous metals, heat generators without direct contact with coke were needed. Some foundry steels and nonferrous metals were melted in gas or coke fired furnaces, packed in either tight-lidded crucibles or open-top crucibles that used slag to cover the bath and keep out carbon. These units, however, could generate only relatively small amounts per melt because the crucible had to be lifted and handled by hand. For larger batches of metal, foundries, especially steel, also used open hearth furnaces that burned oils or gases and recycled hot exhaust fumes. Heating air that wafted over the bath, the furnace melted steel and maintained high pouring temperatures for the metal without direct carbon content. These units, however, were fairly complex and are only cost effective for large batches of steel; in 1956 they accounted for only eleven percent of steel melting furnaces but produced nearly forty-nine percent of the total production.[120]

Of the electric melting means available to foundries, the arc type proved to be the most widely used furnace through the

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[116]Hartley, p. 119.

[117]Dr. Rudolf Hohage and Bernard Matuschka, "High-Frequency Furnace Produces Pure Steel," Steel 87 (December 11, 1930): 55.

[118]Johnson and Seiger, Metallurgical and Chemical Engineering.

[119]Ibid.

[120]Heine and Rosenthal, p. 376.

early 1930s. By 1930, the furnace was capable of using slag to heat the bath. After the melt had been achieved, especially with a vertical electrode furnace, electricity continued to heat the slag, and, being hotter than the metal bath, kept its temperature higher. One disadvantage, however, was that the arc furnace did not induce any electric stirring or mixing that evenly heated the bath and encouraged slag to converge on the top. These units required additional substances to produce a boiling action, or machinery or workers to physically stir. Although many steel foundries used electric furnaces successfully, these limitations ensured that crucible melting and open hearths would continue to dominate steel foundries through the 1940s.[121]

While steel foundries did not immediately accept electric furnaces, by 1956 arc furnaces, with the addition of stirring means, melted forty-nine percent of the foundry steel.[122] The initial impact on the nonferrous industry was considerably more significant. During one seven month period in 1920, the number of electric furnaces in the nonferrous industry jumped forty percent.[123]

Developments continued in induction furnace design for the steel industry. The coreless induction furnace, actually invented in 1917, had overcome many of the disadvantages of crucible, arc, and early cored induction furnaces. Introduced by the Ajax-Northrup company, the high frequency coreless induction furnace provided large batches of iron, melted quickly with an internal stirring action. High power requirements, however prevented it from receiving much commercial attention until 1925.[124]

The furnace utilized a strong alternating current to generate a magnetic field in copper coils, similar to cored induction furnaces, surrounding a large refractory coated steel crucible. That field induced a high alternating current directly in the metals charged into the furnace, without the need for a core or metal bath. As current passed through the metals, natural resistance and discontinuities in the charge dissipated the current in the form of heat. As the charge melted, electric current began to pass through the metals independently, creating eddy currents that accelerated melting and, when the metal was

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[121]Hohage and Matuschka, Steel.

[122]Heine and Rosenthal, p. 376.

[123]Edwin Cone, "Electric Furnaces and Melting Mediums," Iron Age 106 (October 21, 1920): 1059.

[124]Hohage and Matuschka, Steel, and Dr. E.F. Northrup, "Tonnage Melted by Coreless Induction," Iron Age 127 (January 15, 1931): 128.

fully molten, acted to thermally stir the bath.[125]

Through the 1930s, coreless induction furnaces gained in usage. Manufacturers recommended them for nonferrous alloys, steel alloys, silicon steels, and low carbon irons.[126] However, one of the original developers of the coreless furnace stated that for a new device to catch on it "must not be replaceable by something practically more simple, less expensive, and more efficient."[127] Thus the cheaper and higher volume cupola method of melting continued to dominate iron foundries.

However, as power became more consistently available and controls became stronger, furnace sizes grew and competed at marginal levels with smaller cupolas.[128] By 1935, some experimentation of electric iron melting had taken place. The Riley Stoker Company produced white iron by an electric arc and resulted in a slightly better product with less loss than they had with their hearth furnace, although they probably incurred higher operating expenses.[129]

By the late 1950s arc and coreless induction melting came to dominate the electric steel and nonferrous foundry industry. By 1960, the number of electric induction furnaces had risen nearly ninety percent since 1956, while the number of arc furnaces had risen only thirty.[130] By 1963 induction furnaces, at 2,159, outnumbered arc furnaces by 909, and together they out numbered cupolas by 592.[131] As discussed earlier, the majority of cupolas were used in the gray iron industry, leaving electric furnaces to fill the gap throughout the rest of the foundry industry.

Electric furnaces did, however, have several advantages over other melting means. They started from a cold charge and, as with the furnaces installed at Southern Ductile, produced their first melt in twenty-four minutes.[132] This reduced the need for

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[125]Sylvia, p. 256, and Heine and Rosenthal, p. 393.

[126]Dr. E.F. Northrup, "Typical Installations of Coreless Induction Furnaces," Iron Age 127 (January 29, 1931): 228.

[127]Ibid.

[128]Northrup, Iron Age (January 15, 1931).

[129]"Better Product with Electric Iron," Electric World 105 (July 6, 1935): 1715.

[130]"Inventory of Foundry Equipment," Foundry 88 (May, 1960): 139, and Hiene and Rosenthal, p. 376.

[131]Metal Casting Industry Census and Guide.

[132]Southern Ductile Casting Company, "Permit Application for Manufacturing or Processing Operation."

a night crew to charge and prepare cupolas that took several hours to raise the internal temperature high enough to support melting and permit the first charge to "soak" and preheat before the first melt could be tapped.[133]

Second, two developments also changed the usage patterns of induction furnaces: in 1948, ductile iron was introduced and, in the 1970s, the nation experienced an air pollution crisis. Ductile iron needed to maintain low sulphur levels because sulphur reacts with magnesium fairly easily, and that reaction both reduces the level of magnesium available to create nodular graphite and increases the level of toxic emissions. Electric furnaces provided an excellent medium because of the elimination of high-sulphur coke used in cupolas, as well as granting tighter chemical control.[134] Second, cupola emissions are high in other toxins, oxides, smoke, and solid waste created by burning coke. Electric furnaces, which do not burn, considerably reduce the level of emissions.

By the 1970s the cost and availability of electricity had become conducive to electric melting, especially when incorporated with pollution and chemical concerns. In 1977, the year Southern Ductile began exploring electric melting, the energy cost of operating induction furnaces at their plant was just one third greater than the cost of coke.[135] Although output from the larger furnaces was limited to just sixty-three percent of the cupolas, and they required additional machinery, installation, and were considerably more expensive to purchase, the furnaces had other economic advantages. They reduced the needed for extraneous pollution equipment to clean cupola emissions, produced a more refined product, and produced a faster initial output than cupolas.

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[133]Heine, pp. 461-464.

[134]Patton, Iron Age.

[135] In a letter from electric control supplier, Southern Engineering and Equipment Company to Vulcan Engineering, Southern Ductile's prime construction contractor, the estimated monthly cost of operating a single coreless induction furnace based on an Alabama Power rate schedule for commercial customers was $10,917 based on 170 hours of melting per month at a production rate of 3.5 tons per hour delivering to 595 tons of iron per month. According to John W. Bolton in "Expounds Principles of Successful Cupola Operation-I," Foundry 56 (April 15, 1928): 292, cupolas generally required one ton of coke per ten tons of iron melted. Thus the monthly cost to operate Southern Ductile's cupolas equated to $7318 based on the requirement of 59.5 tons of coke needed to melt 595 tons of iron at $123 per ton of coke as listed in "Prices of Foundry Metals and Coke," Foundry Management and Technology 105 (January, 1977): 140.

Induction furnaces proved to be a successful tool for the foundry industry as a whole, so much so that from 1963 to 1986, the number of induction furnaces increased almost two and one half times. Arc furnaces, already only sixty percent of the number of induction furnaces in 1963, dropped to only fourteen percent in 1986. By 1986, 4,285 more induction furnaces were in operation than arc furnaces, accounting for eighty-seven percent of all electric melting. Over the same period, the number of cupolas dropped by seventy percent, and the number of crucible furnaces dropped by forty percent.[136]

While electricity had been used to melt foundry metals for over a century, it did not successfully replace cupola melting in iron foundries until cupolas became too expensive to operate as air pollution requirements dictated clean effluent to environment. Many small cupola firms had to close because they did not have the capital to install either new melting or pollution control systems, while many large firms maintained the higher output of cupolas with the added control equipment.

Those smaller firms that could obtain capital to alter their melting did so, and many replaced their cupolas with electric furnaces. Although their start-up, installation, and operating costs increased, they were able to produce a higher quality product and meet all necessary regulations. Induction furnaces were not limited to the United States. Firms in Europe, although not necessarily as concerned with pollution regulations, switched from cupola to electric melting, citing quality reasons. In 1977, Edwin Preston, Ltd., a British foundry specializing in measuring weights, replaced its cupolas with induction furnace to "bring...better control of the melt mix and simpler and quicker correction of the mix after on-the-spot analysis...[enabling] the firm to use a larger portion of scrap to pig iron." That same year, Bertrams, an Edinburgh, Scotland, paper machinery manufacturer also switched to electric furnaces to "produce castings of a high standard to all iron specifications and ensure a reliable delivery service."[137]

Southern Ductile's shift to electric induction melting occurred during a period when several similar sized firms switched. Although the new medium could not produce as high a volume as a cupola, production still increased on additional shifts, probably as the company's quality and demand grew while less capitalized competitors were forced to close. Growing demand for its products eventually led to the installation of two more furnaces and the purchase of two other foundries in the late 1980s.

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[136] Metal Casting Industry Census and Guide.

[137] "More Foundries move from Cupola to Electric Melting," Metallurgia and Metal Forming 44 (May, 1977): 217.

APPENDIX C

This appendix examines primary foundry technologies and business arrangements that provide a broader industrial context within which to examine Jones Foundry.

Foundries reshape scrap or bulk metals into products by melting and recasting the molten metal in pre-formed molds. The basic mold-making procedure requires that wet sand be packed in a rigid box, or flask, over a pattern resembling the final casting. After the pattern is removed, the wet sand retains the pattern's shape. Most castings require two halves, a top (cope) and bottom (drag), to complete a mold. They are prepared similarly except that each uses a pattern corresponding to its respective half, and the cope includes a spout (sprue) for molten metals to be poured into. Both halves have intermediary channels, or runners, for iron to flow through to reach the mold cavity, and small openings called gates through which the iron enters the mold cavity. After each half is prepared, a rigid, organically-bonded and baked sand structure (core), if required, is inserted into the mold, creating hollow areas within the solidified casting. Finally, the cope and drag are assembled with pattern impressions opposing, and molten metal is poured down the sprue through runners and gates into the mold cavity.

After the iron cools and solidifies, the core breaks down from the latent heat and the casting is removed (shaken out) from the sand. The casting is cleaned by removing the solidified sprue, runners, and any other excess surface metal or oxides. The sand, which now includes the collapsed core, is infused with fresh sand and water, and reused.

These basic procedures have been used for several centuries, with the only primary changes (until the latter 20th century) occurring in the level of automation. The industry as a whole probably didn't change much from the first foundry in the United States, which cast iron pots along the Saugus River, Massachusetts, in 1642, through the early 1800s.[138] During the nineteenth century, the industry grew rapidly as iron availability and demand increased. By 1914, the U.S. had 5,942 foundries supported by several trade journals and an active technical community.[139] The majority were jobbing shops. In 1955, of the 5650 foundries in the United States, eighty-six percent were either primarily or exclusively jobbing

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[138]See J. Gerin Sylvia, Cast Metal Technology (Reading, MA: Addison-Wesley Publishing, Co., 1977) p. 7, for a brief history of the foundry industry.

[139]See "Foundry Count," Foundry 44 (September, 1916): 376.

foundries.[140] This level remained relatively consistent; it was seventy-six percent in 1971 and eighty percent in 1986.[141]

By definition, a jobbing firm manufactures items to order as opposed to production or captive foundries whose products are made, owned, and stored by the company until they are sold as finished items or used in the assembly of more complex pieces. An economic benefit of jobbing is that stocks can be held low and raw materials purchased as production orders come in, minimizing initial capital outlays for storage and materials. Additionally, most jobbing firms do not build or own patterns. Their customers either provide their own or contract for their construction, requiring only storage and possibly repair services from the foundry.

Jobbing firms must also maintain a high degree of flexibility to serve their numerous customers and products. For many, contracts consist of a very limited number of products, or complicated or large castings that do not lend themselves to automated equipment designed to mass produce a single product or limited size.[142] As a rule, many jobbing firms also chose not automate in order to remain competitive. By reducing the expense of equipment, they operated on low budgets with simple labor-intensive procedures and relatively high labor costs. Additionally, because they existed on small orders, profits were generally relatively low. Thus, when their products and operations were conducive to mechanization, many firms probably found it financially difficult to automate.

Those firms that chose to automate tended to be mostly the larger production firms. In 1960, all foundries that employed over one thousand employees were production firms but, in 1971 they accounted for less than one percent of the total number of foundries. Each of these firms had some form of sand handling system and eighty percent had mechanized mold and core handling. Of the foundries that employed between one and ninety-nine workers, accounting for over eighty-two percent of the industry in 1971, less than thirty percent had a sand system; less than fifteen percent had automated mold handling; and less than eight

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[140]"6208 Plants Casting Metals in the United States and Canada," Foundry 83 (August, 1955): 114.

[141]For a statistical description of the foundry industry in 1987 with historical information dating back to the mid 1960s see Metal Casting Industry Census Guide, (Cleveland: Foundry Management and Technology, Penton Publishing, 1987).

[142]For a discussion of foundry automation see Bode J. Morin, "Cast in Grey: Evolving Mass Production Foundry Practices within a Southern Industrial Community," (M.S. thesis, Michigan Technological University, 1995) pp. 98-101.

percent had core handling.[143] While these statistics neither differentiate between jobbing and production shops nor correspond to exact dates, the total number of foundries changed little between 1960 and 1971, and the operational tendency of jobbing firms to be small and labor-intensive place them in the vast majority firms without automated equipment.

Jones Foundry's size and level of technological advancement were typical for most jobbing firms during the firms first twenty years, somewhat advanced for its next twenty, and fairly modern and advanced for its next twenty.

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[143]For a description of what technologies foundries had implemented or were intending to implement in 1960 see "Foundries to Spend More for Plant and Equipment," Foundry 88 (May, 1960): 137 and "Inventory of Foundry Equipment," Foundry 88 (May, 1960).

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